DECLARATION OF JUNE ANN MUNFORD

1. My name is June Ann Munford. I am over the age of 18, have personal knowledge of the facts set forth herein, and am competent to testify to the same.

2. I earned a Master of Library and Information Science (MLIS) from the University of Wisconsin-Milwaukee in 2009. I have over ten years of experience in the library/information science field. Beginning in 2004, I have served in various positions in the public library sector including Assistant Librarian, Youth Services Librarian and Library Director. I have attached my Curriculum Vitae as Appendix CV.

3. During my career in the library profession, I have been responsible for materials acquisition for multiple libraries. In that position, I have cataloged, purchased and processed incoming library works. That includes purchasing materials directly from vendors, recording publishing data from the material in question, creating detailed material records for library catalogs and physically preparing that material for circulation. In addition to my experience in acquisitions, I was also responsible for analyzing large collections of library materials, tailoring library records for optimal catalog

search performance and creating lending agreements between libraries during my time as a Library Director.

4. I am fully familiar with the catalog record creation process in the library sector. In preparing a material for public availability, a library catalog record describing that material would be created. These records are typically written in Machine Readable Catalog (herein referred to as "MARC") code and contain information such as a physical description of the material, metadata from the material's publisher, and date of library acquisition. In particular, the 008 field of the MARC record is reserved for denoting the date of creation of the library record itself. As this typically occurs during the process of preparing materials for public access, it is my experience that an item's MARC record indicates the date of an item's public availability.

5. Typically, in creating a MARC record, a librarian would gather various bits of metadata such as book title, publisher and subject headings among others and assign each value to a relevant numerical field. For example, a book's physical description is tracked in field 300 while title/attribution is tracked in field 245. The 008 field of the MARC record is reserved for denoting the creation of the library record itself. As this is the only date reflecting the inclusion of said materials within the library's collection, it is my experience

that an item's 008 field accurately indicates the date of an item's public availability.

6. I have reviewed Exhibit APPLE-1021, "Controller for Driving a Piezoelectric Actuator at Resonance" by Jack Aldrich, et. al as published in *NASA Tech Briefs*, April 2008.

7. Attached hereto as Appendix ALDRICH01 is a true and correct copy of the MARC record for a digital edition of *NASA Tech Briefs* as held by the Penn State University library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix ALDRICH01 accurately describes the title, author, publisher, and ISSN number of *NASA Tech Briefs.* The 'Journal Details' field on page 2 indicates this collection contains the April 2008 edition of *NASA Tech Briefs* containing "Controller for Driving a Piezoelectric Actuator at Resonance".

8. Attached hereto as Appendix ALDRICH02 is a true and correct copy of "Controller for Driving a Piezoelectric Actuator at Resonance" as published in *NASA Tech Briefs* as held by the Penn State University library. I secured this PDF copy myself from the library's digital collection. In comparing Exhibit APPLE-1021 to Appendix ALDRICH02, it is my determination that

Exhibit APPLE-1021 is a true and correct copy of "Controller for Driving a Piezoelectric Actuator at Resonance" by Jack Aldrich, et. al as published in *NASA Tech Briefs* April 2008.

9. The 008 field of the MARC record in Appendix ALDRICH01 indicates the date of record creation. The 008 field of Appendix ALDRICH01 indicates the Penn State University library first acquired this journal as of December 9, 1999 and holds the journal in perpetuity. Considering this information, it is my determination that the digital edition of *NASA Tech Briefs* April 2008 and therefore "Controller for Driving a Piezoelectric Actuator at Resonance" was made available to the public shortly after its initial release in April 2008.

10. Attached hereto as Appendix ALDRICH03 is a true and correct copy of the MARC record for the physical edition of *NASA Tech Briefs* as held by the Penn State University library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix ALDRICH03 accurately describes the title, author, publisher, and ISSN number of *NASA Tech Briefs.* The 'Availability' field on page 3 indicates this collection contains the April 2008 edition of *NASA Tech Briefs* containing "Controller for Driving a Piezoelectric Actuator at Resonance".

11. Attached hereto as Appendix ALDRICH04 is a true and correct copy of "Controller for Driving a Piezoelectric Actuator at Resonance" as published in *NASA Tech Briefs* as held by the Penn State University library. I secured these scans myself from the library's collection. In comparing Exhibit APPLE-1021 to Appendix ALDRICH04, it is my determination that Exhibit APPLE-1021 is a true and correct copy of "Controller for Driving a Piezoelectric Actuator at Resonance" by Jack Aldrich, et. al as published in *NASA Tech Briefs* April 2008.

12. The 008 field of the MARC record in Appendix ALDRICH03 indicates the date of record creation. The 008 field of Appendix ALDRICH03 indicates the Penn State University library first acquired the physical edition of this journal as of September 16, 1982 and held the journal until 2010. Considering this information, it is my determination that the physical edition of *NASA Tech Briefs* April 2008 and therefore "Controller for Driving a Piezoelectric Actuator at Resonance" was made available to the public shortly after its initial release in April 2008.

13. I have been retained on behalf of the Petitioner to provide assistance in the above-illustrated matter in establishing the authenticity and public

availability of the documents discussed in this declaration. I am being compensated for my services in this matter at the rate of $200.00 per hour plus reasonable expenses. My statements are objective, and my compensation does not depend on the outcome of this matter.

14. I declare under penalty of perjury that the foregoing is true and correct. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 3/4/2024

June Ann Munford

APPENDIX CV

June A. Munford
Curriculum Vitae

Education

University of Wisconsin-Milwaukee - MS, Library & Information Science, 2009
Milwaukee, WI

- Coursework included cataloging, metadata, data analysis, library systems, management strategies and collection development.
- Specialized in library advocacy, cataloging and public administration.

Grand Valley State University - BA, English Language & Literature, 2008
Allendale, MI

- Coursework included linguistics, documentation and literary analysis.
- Minor in political science with a focus in local-level economics and government.

Professional Experience

Researcher / Expert Witness, October 2017 – present
Freelance ● Pittsburgh, Pennsylvania & Grand Rapids, Michigan

- Material authentication and public accessibility determination. Declarations of authenticity and/or public accessibility provided upon research completion. Experienced with appeals and deposition process.

- Research provided on topics of public library operations, material publication history, digital database services and legacy web resources.

- Past clients include Alston & Bird, Arnold & Porter, Baker Botts, Fish & Richardson, Erise IP, Irell & Manella, O'Melveny & Myers, Perkins-Coie, Pillsbury Winthrop Shaw Pittman and Slayden Grubert Beard.

Library Director, February 2013 - March 2015
Dowagiac District Library ● Dowagiac, Michigan

- Executive administrator of the Dowagiac District Library. Located in

Southwest Michigan, this library has a service area of 13,000, an annual operating budget of over $400,000 and total assets of approximately $1,300,000.

● Developed careful budgeting guidelines to produce a 15% surplus during the 2013-2014 & 2014-2015 fiscal years while being audited.

● Using this budget surplus, oversaw significant library investments including the purchase of property for a future building site, demolition of existing buildings and building renovation projects on the current facility.

● Led the organization and digitization of the library's archival records.

● Served as the public representative for the library, developing business relationships with local school, museum and tribal government entities.

● Developed an objective-based analysis system for measuring library services - including a full collection analysis of the library's 50,000+ circulating items and their records.

November 2010 - January 2013
Librarian & Branch Manager, Anchorage Public Library ● Anchorage, Alaska

● Headed the 2013 Anchorage Reads community reading campaign including event planning, staging public performances and creating marketing materials for mass distribution.

● Co-led the social media department of the library's marketing team, drafting social media guidelines, creating original content and instituting long-term planning via content calendars.

● Developed business relationships with The Boys & Girls Club, Anchorage School District and the US Army to establish summer reading programs for children.

June 2004 - September 2005, September 2006 - October 2013
Library Assistant, Hart Area Public Library
Hart, MI

● Responsible for verifying imported MARC records and original MARC

cataloging for the local-level collection as well as the Michigan Electronic Library.

● Handled OCLC Worldcat interlibrary loan requests & fulfillment via ongoing communication with lending libraries.

Professional Involvement

Alaska Library Association - Anchorage Chapter
● Treasurer, 2012

Library Of Michigan
● Level VII Certification, 2008
● Level II Certification, 2013

Michigan Library Association Annual Conference 2014
● New Directors Conference Panel Member

Southwest Michigan Library Cooperative
● Represented the Dowagiac District Library, 2013-2015

Professional Development

Library Of Michigan Beginning Workshop, May 2008
Petoskey, MI
● Received training in cataloging, local history, collection management, children's literacy and reference service.

Public Library Association Intensive Library Management Training, October 2011
Nashville, TN
● Attended a five-day workshop focused on strategic planning, staff management, statistical analysis, collections and cataloging theory.

Alaska Library Association Annual Conference 2012 - Fairbanks, February 2012
Fairbanks, AK
● Attended seminars on EBSCO advanced search methods, budgeting, cataloging, database usage and marketing.

Depositions

2019 ● Fish & Richardson

Apple v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282 and 39521-00421IP2)

2019 ● Erise IP

Implicit, LLC v. Netscout Systems, Inc (Civil Action No. 2:18-cv-53-JRG)

2019 ● Perkins-Coie

Adobe Inc. v. RAH Color Technologies LLC (Cases IPR2019-00627, IPR2019-00628, IPR2019-00629 and IPR2019-00646)

2020 ● O'Melveny & Myers

Maxell, Ltd. v. Apple Inc. (Case No. 5:19-cv-00036-RWS)

2021 ● Pillsbury Winthrop Shaw Pittman LLP

Intel v. SRC (IPR2020-1449)

2022 ● Perkins-Coie

Realtek v. Future Link (IPR2021-01182)

2023 ● Fish & Richardson

Neuroderm Ltd. v. Abbvie, Inc (Case No. PGR2022-00040)

2023 ● Fish & Richardson

Nearmap US Inc. v. Pictometry International Corp. (IPR2022-00735)

2023 ● Fish & Richardson

Samsung Electronics v. MemoryWeb LLC (Case No. 39843-0136PS1)

2023 ● Pillsbury Winthrop Shaw Whitman LLP

Gravel Rating Systems v. Costco Wholesale Corp. (Civil Action No. 4:21-cv-149-ALM)

Limited Case and Clientele History

Alston & Bird

- Ericsson

  v. Collision Communications (IPR2022-01233)

- Nokia

  v. Neptune Subsea, Xtera (Case No. 1:17-cv-01876)

- Universal Electronics Inc

  v. Roku Inc (IPR2022-00818)

Arnold & Porter

- Ivantis

  v. Glaukos (Case No. 8:18-cv-00620)

- Samsung

  v. Jawbone (Case No. 2:21-cv-00186)

Benesch Friedlander Coplan & Aronoff

- Voyis

  v. Cathx (Case No. 5:21-cv-00077-RWS)

Erise I.P.

- Apple
  - v. Ericsson Inc. (IPR2022-00715)
  - v. Future Link Systems (IPRs 6317804, 6622108, 6807505, and 7917680)
  - v. INVT (Case No. 20-1881)
  - v. Navblazer LLC (IPR2020-01253)
  - v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)
  - v. Quest Nettech Corp (Case No. 2:19-cv-00118-JRG)
  - v. Telefonaktiebolaget LM Ericsson (IPR2022-00275)

- Fanduel
  - v. CGT (Case No. 19-1393)

- Garmin
  - v. Phillips North America LLC (Case No. 2:19-cv-6301-AB-KS)

- Netscout
  - v. Longhorn HD LLC (Case No. 2:20-cv-00349)
  - v. Implicit, LLC (Civil Action No. 2:18-cv-53-JRG)

- Sony Interactive Entertainment LLC
  - v. Bot M8 LLC (IPR2020-01288)
  - v. Infernal Technology LLC (Case No. 2:19-CV-00248-JRG)

- Unified Patents

v. GE Video Compression (Civil Action No. 2:19-cv-248)

Fish & Richardson

- Apple

  v. AliveCor (3:21-cv-03958)

  v. LBS Innovations (Case No. 2:19-cv-00119-JRG-RSP)

  v. Koss Corporation (IPR2021-00305)

  v. Masimo (IPR 50095-0012IP1, 50095-0012IP2, 50095-0013IP1, 50095-0013IP2, 50095-0006IP1, 50095-0135IP1)

  v. Neonode (Case No. 21-cv-08872-EMC)

  v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)

- Dell

  v. Neo Wireless (IPR2022-00616)

- Dish Network

  v. Entropic Communications, LLC (Case No. 2:2023-CV-01043)

  v. Realtime Adaptive Streaming (Case No. 1:17-CV-02097-RBJ)

  v. TQ Delta LLC (Case No. 18-1798)

- Evapco Dry Cooling

  v. SPG Dry Cooling (IPR2021-00688)

- Genetec

  v. Sensormatic Electronics (Case No. 1:20-CV-00760)

- Huawei

v. Bell Northern Research LLC (IPR2019-01174)

- Kianxis

  v. Blue Yonder (Case No. 3:20-cv-03636)

- LG Electronics

  v. Bell Northern Research LLC (Case No. 3:18-cv-2864-CAB-BLM)

- Metaswitch

  v. Sonus Networks (IPR2018-01719)

- Microsoft

  v. Throughputer Inc (IPR2022-00757)

- Mom Enterprises

  v. Ddrops Company (Case No. 1:22-cv-00332)

- MLC Intellectual Property

  v. MicronTech (Case No. 3:14-cv-03657-SI)

- Nearmap Inc

  v. EagleView Technologies (IPR2022-01009)

- Neuroderm Ltd.

  v. Abbvie, Inc (Case No. PGR2022-00040)

- Realtek Semiconductor

v. Future Link (IPR2021-01182)

- Quectel

  v. Koninklijke Philips (Case No. 1:20-cv-01710)

- Samsung

  v. Aire Technology (IPR2022-00877)

  v. Bell Northern Research (Case No. 2:19-cv-00286-JRG)

  v. Communication Technologies Inc (IPR2022-01221)

  v. Jawbone Innovations (IPR2022-00865)

  v. MemoryWeb LLC (IPR2022-00885)

  v. Dodots Licensing Solutions (IPR2023-00701)

  v. Telefonaktiebolaget LM Ericsson (IPR2021-00615)

- Texas Instruments

  v. Vantage Micro LLC (IPR2020-01261)

- Xilinx

  v. Sentient Sensors LCC (Case No. 1:22-cv-00173)

Irell & Manella

- Curium

O'Melveny & Myers

- Apple

  v. Maxell (Case No. 5:19-cv-00036-RWS)

- Micron Technology Inc.

  v. Besang Inc (IPR2023-00900)

- Samsung

  v. Daedalus Prime LLC (1335 Investigation)

Perkins-Coie

- Heru Industries

  v. The UAB Research Foundation (IPR2022-01148)

- Intel Corporation

  v. BitMICRO (Case No. 5:23-cv-00625)

- Realtek Semiconductor

  v. Future Link (IPR2021-01182)

- Twitter Inc

  v. VOIP-Pal.com (Case No. 3:20-cv-02397-JD)

- TCL Industries

  v. Koninklijke Philips NV (IPR2021-00495, IPR2021-00496 and IPR2021-00497)

Pillsbury Winthrop Shaw Pittman

- Intel

  v. FG SRC LLC (Case No. 6:20-cv-00315)

- Gravel Rating Systems

v. Costco (Case No. 4:21-cv-149)
v. Lowe's Home Centers (Case No. 4:21-cv-150)
v. T-Mobile USA (Case No. 4:21-cv-152)
v. Kohl's Inc. (Case No. 4:21-cv-258)
v. Under Armor (Case No. 4:21-cv-356)

Quinn Emanuel

- Wolfspeed

  v. The Trustees of Purdue University (Case No. 1:2021-cv-00840)

Stern, Kessler, Goldstein & Fox

- Preliminary Research

Sheppard, Mullin, Richter & Hampton LLP

- Cadence Design Systems Inc.

  v. Semiconductor Design Technologies (Case No. 3:23-cv-01001)

APPENDIX ALDRICH01

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https://catalog.libraries.psu.edu/catalog/43006595/marc_view
05.02.2024

MARC View

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210	0		a| NASA tech briefs b| (Wash., D.C. 1976. Online)
222		0	a| NASA tech briefs b| (Washington, D.C. 1976. Online)
245	0	0	a| NASA tech briefs h| [electronic resource] / c| National Aeronautics and Space Administration.
246	1		a| National Aeronautics and Space Administration tech briefs
246	1		a| NTB
260			a| [Washington, D.C.] : b| National Aeronautics and Space Administration, c| [1976]-
260	2		3| Spring 1985- : a| New Yor, NY : b| Associated Business Publications
260	3		3| <2009- > : a| New York, NY : b| Tech Briefs Media Group
310			a| Monthly
362	1		a| Print began with vol. 1, no. 1 (spring 1976).
500			a| "NASA tech briefs is an official publication of NASA."
500			a| "Engineering solutions for design & manufacturing."
506			3| Use copy f| Restrictions unspecified 2| star 5| MiAaHDL
520			a| Features exclusive reports of innovations developed by NASA and its industry partners/contractors that can be applied to develop new/improved products and solve engineering or manufacturing problems. Authored by the engineers or scientists who did the work, the briefs span a wide array of fields, including electronics, physical sciences, materials, computer software, mechanics, machinery/automation, manufacturing/fabrication, mathematics/information sciences, and life sciences. NASA Tech Briefs also contains feature articles on successful NASA spinoffs, profiles of NASA tech transfer resources, news briefs, and application stories. Regular columns describe new patents, industry products, software, and literature.
538			a| Mode of access: World Wide Web.
583	1		a| digitized c| 2019 h| HathiTrust Digital Library l| committed to preserve 2| pda 5| MiAaHDL
583	1		a| digitized c| 2010 h| HathiTrust Digital Library l| committed to preserve 2| pda 5| MiAaHDL
588			a| Description based on print version record.
588			a| Latest issue consulted: Vol. 40, no. 10 (October 2016) (nasatech.com viewed Nov. 2, 2016).
610	1	0	a| United States. b| National Aeronautics and Space Administration v| Periodicals.
610	1	7	a| United States. b| National Aeronautics and Space Administration. 2| fast 0| (OCoLC)fst00528469
710	1		a| United States. b| National Aeronautics and Space Administration.
770	0		t| Motion design (New York, N.Y. : Online) x| 2642-0937 w| (DLC) 2019200102 w| (OCoLC)1089396999
770	0		t| Photonics & imaging technology (Online) x| 2642-0988 w| (DLC) 2019200104 w| (OCoLC)1089397914
770	0		t| Sensor technology (New York, N.Y. Online) x| 2642-102X w| (DLC) 2019200106 w| (OCoLC)1089398291
776	0	8	i| Print version: t| NASA tech briefs x| 0145-319X w| (DLC) 83645327 w| (OCoLC)2600819
856	4	0	u| http://SK8ES4MC2L.search.serialssolutions.com/?V=1.0&L=SK8ES4MC2L&S=JCs&C=NASATECBRW&T=marc
910			a| CONSER online
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Meta v. Resonant
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NASA tech briefs [electronic resource] / National Aeronautics and Space Administration

Additional Titles: NASA tech briefs (Wash., D.C. 1976. Online), National Aeronautics and Space Administration tech briefs, and NTB

Published: [Washington, D.C.] : National Aeronautics and Space Administration, [1976]-
Spring 1985- : New Yor, NY : Associated Business Publications
<2009- > : New York, NY : Tech Briefs Media Group

Additional Creators: United States. National Aeronautics and Space Administration

Access Online
serialssolutions.com

Restrictions on Access:
Restrictions unspecified

Summary:
Features exclusive reports of innovations developed by NASA and its industry partners/contractors that can be applied to develop new/improved products and solve engineering or manufacturing problems. Authored by the engineers or scientists who did the work, the briefs span a wide array of fields, including electronics, physical sciences, materials, computer software, mechanics, machinery/automation, manufacturing/fabrication, mathematics/information sciences, and life sciences. NASA Tech Briefs also contains feature articles on successful NASA spinoffs, profiles of NASA tech transfer resources, news briefs, and application stories. Regular columns describe new patents, industry products, software, and literature.

Dates of Publication and/or Sequential Designation:
Print began with vol. 1, no. 1 (spring 1976).

Subject(s):
United States. National Aeronautics and Space Administration—Periodicals
United States. National Aeronautics and Space Administration

ISSN:
2474-8498

Publication Frequency:
Monthly

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Mode of access: World Wide Web.

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META-1022, p. 22
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NASA tech briefs (Washington, D.C. 1976)

ISSN: 0145-319X

Journal Details () ▼ ()

04/01/1999 to Present in Advanced Technologies & Aerospace Database (../../log?L=SK8ES4MC2L&D=P5Z&J=NASATECBRW&P=EJP&PT=EZProxy&A=NASA+tech+briefs+%28Washing

2008 to Present in Freely Accessible Science Journals (../../log?L=SK8ES4MC2L&D=FRP&J=NASATECBRW&P=EJP&PT=EZProxy&A=NASA+tech+briefs+%28Washington%2(

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META-1022, p. 23
Meta v. Resonant
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META-1022, p. 25
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2008 April

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1 Table of contents

Anonymous. **NASA Tech Briefs; New York** Vol. 32, Iss. 4, (Apr 2008): 4,6.

Full Text

Details Full text - PDF (137 KB)

META-1022, p. 26
Meta v. Resonant
IPR2025-00823

2 Motion Control Components Lend Hand to Biomedical Applications

Anonymous. **NASA Tech Briefs; New York** Vol. 32, Iss. 4, (Apr 2008): 6A,8A,9A.

Full Text

Details Full text - PDF (287 KB)

3 2007 Product of the Year Winners

Anonymous. **NASA Tech Briefs; New York** Vol. 32, Iss. 4, (Apr 2008): 8.

Full Text

Details Full text - PDF (86 KB)

4 PRODUCT OF THE MONTH

Anonymous. **NASA Tech Briefs; New York** Vol. 32, Iss. 4, (Apr 2008): 8.

Full Text

Details Full text - PDF (86 KB)

5 This Month in NASA History

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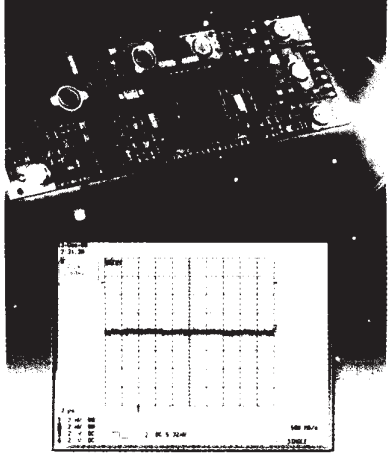
Meta v. Resonant
IPR2025-00823

APPENDIX ALDRICH02

Satellite Power Design Simplified

Mx Series Platform



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Using Transponders on the Moon to Increase Accuracy of GPS

Ranging to the Moon would be unaffected by the terrestrial atmosphere.

NASA's Jet Propulsion Laboratory, Pasadena, California

It has been proposed to place laser or radio transponders at suitably chosen locations on the Moon to increase the accuracy achievable using the Global Positioning System (GPS) or other satellite-based positioning system. The accuracy of GPS position measurements depends on the accuracy of determination of the ephemerides of the GPS satellites. These ephemerides are determined by means of ranging to and from Earth-based stations and consistency checks among the satellites. Unfortunately, ranging to and from Earth is subject to errors caused by atmospheric effects, notably including unpredictable variations in refraction.

The proposal is based on exploitation of the fact that ranging between a GPS satellite and another object outside the atmosphere is not subject to error-inducing atmospheric effects. The Moon is such an object and is a convenient place for a ranging station. The ephemeris of the Moon is well known and, unlike a GPS satellite, the Moon is massive enough that its orbit is not measurably affected by the solar wind and solar radiation.

According to the proposal, each GPS satellite would repeatedly send a short laser or radio pulse toward the Moon and the transponder(s) would respond by sending back a pulse and delay information. The GPS satellite could then compute its distance from the known position(s) of the transponder(s) on the Moon.

Because the same hemisphere of the Moon faces the Earth continuously, any transponders placed there would remain continuously or nearly continuously accessible to GPS satellites, and so only a relatively small number of transponders would be needed to provide continuous coverage. Assuming that the transponders would depend on solar power, it would be desirable to use at least two transponders, placed at diametrically opposite points on the edges of the Moon disk as seen from Earth, so that all or most of the time, at least one of them would be in sunlight.

This work was done by Konstantin Penanen and Talso Chui of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov.
NPO-43160

Controller for Driving a Piezoelectric Actuator at Resonance

Unpredictable variations in resonance frequency are tracked.

NASA's Jet Propulsion Laboratory, Pasadena, California

A digital control system based partly on an extremum-seeking control algorithm tracks the changing resonance frequency of a piezoelectric actuator or an electrically similar electromechanical device that is driven by a sinusoidal excitation signal and is required to be maintained at or near resonance in the presence of uncertain, changing external loads and disturbances. Somewhat more specifically, on the basis of measurements of the performance of the actuator, this system repeatedly estimates the resonance frequency and alters the excitation frequency as needed to keep it at or near the resonance frequency. In the original application for which this controller was developed, the piezoelectric actuator is part of an ultrasonic/sonic

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META-1022, p. 40
Meta v. Resonant
IPR2025-00823

drill/corer. Going beyond this application, the underlying principles of design and operation are generally applicable to tracking changing resonance frequencies of heavily perturbed harmonic oscillators.

Resonance-frequency-tracking analog electronic circuits are commercially available, but are not adequate for the present purpose for several reasons:

- The input/output characteristics of analog circuits tend to drift, often necessitating recalibration, especially whenever the same controller is used in driving a different resonator.
- In the case of an actuator in a system that has multiple modes characterized by different resonance frequencies, an analog controller can tune erroneously to one of the higher-frequency modes.
- The lack of programmability of analog controllers is problematic when faults occur, and is especially problematic for preventing tuning to a higher-frequency mode.

In contrast, a digital controller can be programmed to restrict itself to a specified frequency range and to maintain stability even when the affected resonator is driven at high power and subjected to uncertain disturbances and variable loads.

The present digital control system (see figure) is implemented by means of an algorithm that comprises three main subalgorithms: a hill-climbing control algorithm, an estimation-based extremum-seeking control (ESC) algorithm, and a supervisory algorithm. The hill-climbing algorithm is useful for coarse tracking to find and remain within the vicinity of the resonance. The ESC algorithm is not capable of coarse resonance tracking, but is capable of fine resonance tracking once the estimates of parameters generated by the hill-climbing algorithm have converged sufficiently. On the basis of the parameter-estimation errors, the supervisory algorithm switches operation to whichever of the other two algorithms performs best at a given time.

For the purpose of the control algorithm, the performance of the actuator is quantified in terms of the ratio between the time-averaged drive-voltage amplitude and the time-averaged drive current amplitude during a sampling time period. In the hill-climbing algorithm, the excitation frequency during the next sampling period is incremented or decremented by an arbitrary fixed step. If the increment or decrement results in an increase in the current/voltage ratio, then the direction of change (increase or decrease, respectively) of frequency is accepted and another such change (increment or decrement, respectively) is made during the following sampling period. If, on the other hand, the increment or decrement results in a decrease in the current/voltage ratio, then the direction of change of frequency during the following sampling period is reversed. The process as described thus far is repeated, causing the current/voltage performance to climb to one of the resonance peaks and eventually to oscillate about the peak. In order to prevent climbing of one of the undesired higher-frequency resonance peaks, it is necessary to choose the starting excitation frequency near the desired peak and to impose a limit on the excursion from the starting frequency.

Once the excitation frequency has begun to oscillate about the peak, the supervisory algorithm switches operation to the ESC algorithm, which uses past as well as present input/output data to make a least-squares estimate of the resonance frequency. The estimation task involves

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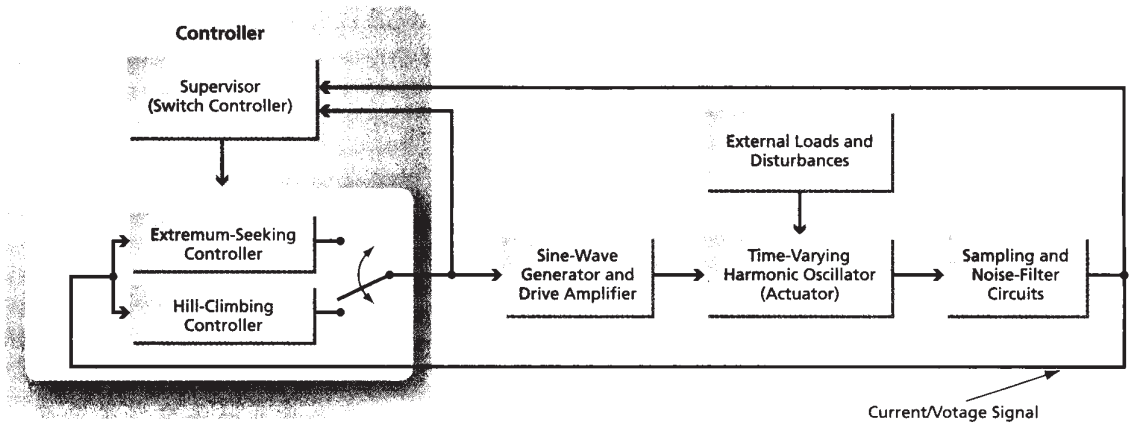

This **Resonance-Tracking Controller** includes three main subsystems that function together to effect a combination of coarse and fine frequency tracking optimized to maintain operation at a desired resonance and avoid undesired resonances.

updating two scalar parameters of a quadratic model that represents the input/output map of the actuator resonance. After each sampling period, the new input/output data pair is added to the collection of past data pairs, such that information regarding the input/output relationship of the actuator increases over time; in other words, as the input/output information comes in, the algorithm tries to improve the fit between the quadratic model near resonance and all the past input/output data up to the current time. Once the estimated parameters have converged sufficiently, the excitation frequency is updated according to a simple formula that represents a maximizer associated with the quadratic model. In the event that the estimates begin to diverge beyond a specified limit, the supervisory algorithm switches operation back to the hill-climbing algorithm.

This work was done by Jack Aldrich, Yoseph Bar-Cohen, Stewart Sherrit, Mircea Badescu, Xiaoqi Bao, and Zensheu Chang of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov. NPO-43519

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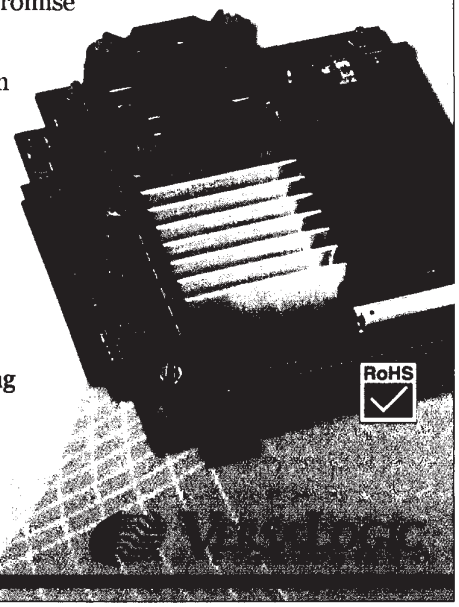

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META-1022, p. 42
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949 a| TL521.3.T43 v.13 Jan.-June 1989 w| LCPER c| 1 i| 000059958598 d| 8/13/2010 l| CATO-2 m| UP-ANNEX q| 2 r| Y s| Y t| PERIODICAL u| 4/8/2008 z| 6540

949 a| TL521.3.T43 v.13 July-Dec.1989 w| LCPER c| 1 i| 000059958604 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/8/2008 z| 6540

949 a| TL521.3.T43 v.14 Jan.-June 1990 w| LCPER c| 1 i| 000059958611 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/8/2008 z| 6540

949 a| TL521.3.T43 v.14 July-Dec.1990 w| LCPER c| 1 i| 000059958628 d| 5/27/2009 l| CATO-2 m| UP-ANNEX q| 1 r| Y s| Y t| PERIODICAL u| 4/8/2008 z| 6540

949 a| TL521.3.T43 v.15 Jan-June 1991 w| LCPER c| 1 i| 000052470059 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.15 July-Dec 1991 w| LCPER c| 1 i| 000052470066 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.16 Jan-June 1992 w| LCPER c| 1 i| 000052470073 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.16 July-Dec 1992 w| LCPER c| 1 i| 000052470080 d| 2/22/2016 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.17 July-Dec 1993 w| LCPER c| 1 i| 000052470103 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.17 Jan-June 1993 w| LCPER c| 1 i| 000052470097 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.17 1993 index w| LCPER c| 1 i| 000052470110 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.18 Jan-June 1994 w| LCPER c| 1 i| 000052470127 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.18 July-Dec 1994 w| LCPER c| 1 i| 000052470134 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.19 Jan-June 1995 w| LCPER c| 1 i| 000052470141 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.19 July-Dec 1995 w| LCPER c| 1 i| 000052470158 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.20 Jan-June 1996 w| LCPER c| 1 i| 000052470165 d| 5/27/2009 l| CATO-2 m| UP-ANNEX q| 1 r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.20 July-Dec 1996 w| LCPER c| 1 i| 000052470172 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.21 Jan-June 1997 w| LCPER c| 1 i| 000052470189 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.21 July-Dec 1997 w| LCPER c| 1 i| 000052470196 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.22 Jan-June 1998 w| LCPER c| 1 i| 000052470202 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.22 July-Dec 1998 w| LCPER c| 1 i| 000052470219 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.23 Jan-June 1999 w| LCPER c| 1 i| 000052470226 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.23 July-Dec 1999 w| LCPER c| 1 i| 000052470233 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/22/2003 z| 6344

949 a| TL521.3.T43 v.24 Jan.-June 2000 w| LCPER c| 1 i| 000048308038 d| 10/24/2002 l| CATO-2 m| UP-ANNEX q| 1 r| Y s| Y t| PERIODICAL u| 4/29/2002 z| 6344

949 a| TL521.3.T43 v.24 July-Dec.2000 w| LCPER c| 1 i| 000048308045 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/29/2002 z| 6344

949 a| TL521.3.T43 v.25 Jan-June 2001 w| LCPER c| 1 i| 000051766337 d| 3/9/2016 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 2/4/2003 z| 6898

949 a| TL521.3.T43 v.25 July-Dec 2001 w| LCPER c| 1 i| 000051766320 d| 3/9/2016 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 2/4/2003 z| 6898

949 a| TL521.3.T43 v.26 Jan-June 2002 w| LCPER c| 1 i| 000052539145 d| 3/9/2016 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 8/14/2003 z| 6898

949 a| TL521.3.T43 v.26 July-Dec 2002 w| LCPER c| 1 i| 000052539152 d| 11/6/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 8/14/2003 z| 6898

949 a| TL521.3.T43 v.27 Jan-June 2003 w| LCPER c| 1 i| 000055020183 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 8/4/2005 z| 6898

949 a| TL521.3.T43 v.27 July-Dec 2003 w| LCPER c| 1 i| 000055020138 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 8/4/2005 z| 6898

949 a| TL521.3.T43 v.28 Jan-June 2004 w| LCPER c| 1 i| 000055020121 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 8/4/2005 z| 6898

949 a| TL521.3.T43 v.28 July-Dec 2004 w| LCPER c| 1 i| 000055020114 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t|

949			a| TL521.3.T43 v.28 July-Dec 2004 w| LCPER c| 1 i| 000055020114 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 8/4/2005 z| 6898
949			a| TL521.3.T43 v.29 Jan-June 2005 w| LCPER c| 1 i| 000055202572 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 3/26/2007 z| 6898
949			a| TL521.3.T43 v.29 July-Dec 2005 w| LCPER c| 1 i| 000055202558 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 3/26/2007 z| 6898
949			a| TL521.3.T43 v.30 Jan-June 2006 w| LCPER c| 1 i| 000055202541 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 3/26/2007 z| 6898
949			a| TL521.3.T43 v.30 July-Dec 2006 w| LCPER c| 1 i| 000055202565 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 3/26/2007 z| 6898
949			a| TL521.3.T43 v.31 Jan-June 2007 w| LCPER c| 1 i| 000059759607 d| 11/2/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 6/8/2009 z| 6898
949			a| TL521.3.T43 v.31 July-Dec 2007 w| LCPER c| 1 i| 000059759935 d| 11/6/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 6/8/2009 z| 6898
949			a| TL521.3.T43 v.32 Jan-June 2008 w| LCPER c| 1 i| 000059759942 d| 3/9/2016 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 6/9/2009 z| 6898
949			a| TL521.3.T43 v.32 July-Dec 2008 & suppl. w| LCPER c| 1 i| 000059759959 d| 11/6/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 6/9/2009 z| 6898
949			a| TL521.3.T43 v.33 Jan-June 2009 w| LCPER c| 1 i| 000059430698 d| 3/9/2016 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 9/15/2011 z| 6898
949			a| TL521.3.T43 v.33 July-Dec 2009 & suppl. w| LCPER c| 1 i| 000059430681 d| 3/9/2016 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 9/15/2011 z| 6898
949			a| TL521.3.T43 v.34 Jan-Apr 2010 w| LCPER c| 1 i| 000059385448 d| 11/6/2015 e| 11/2/2015 l| CATO-2 m| UP-ANNEX r| Y s| Y t| PERIODICAL u| 4/1/2012 z| 6898
949			a| Microfilm F1066 v.6 1981/82 w| ASIS c| 1 i| 000063550047 l| CATO-2 m| UP-ANNEX r| Y s| Y t| MICROFORM u| 11/6/2012 z| 8022
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866		0	8| 0 a| v.6(1981/82)
852	0	1	a| PSt b| UP-ANNEX c| ANNEX h| TL521.3 i| .T43
866		0	8| 0 a| v.1(1976)-v.6:no.3(1981), v.7:no.1(1982), v.7:no.3(1983)-v.9:no.2(1985), v.9:no.4(1985)-v.34:no.4(2010)

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TL521.3.T43 v.22 July-Dec 1998	Bound Journal	Annexed Material
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TL521.3.T43 v.21 Jan-June 1997	Bound Journal	Annexed Material
TL521.3.T43 v.20 July-Dec 1996	Bound Journal	Annexed Material
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TL521.3.T43 v.2 1977	Bound Journal	Annexed Material
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TL521.3.T43 1973/74	Bound Journal	Annexed Material
Microfilm F1066 v.6 1981/82	Microfilm, Microfiche, etc.	Annexed Material

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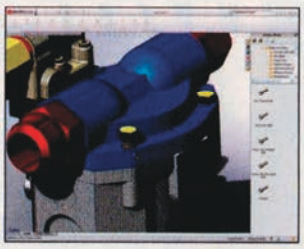
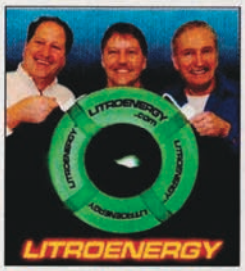
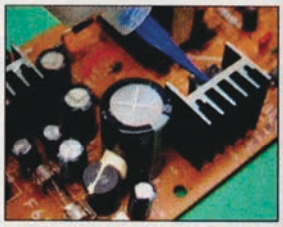


11





88

FEATURES

11 **Special Awards Section: "Create the Future" Design Contest Winners**

28 **Application Briefs**

96 **Eye on Innovation**

SOLUTIONS

30 **Technology Focus: Sensors**

30 Gas Sensors Based on Coated and Doped Carbon Nanotubes

32 Thin-Film Magnetic-Field-Response Fluid-Level Sensor for Non-Viscous Fluids

36 Tactile Robotic Topographical Mapping Without Force or Contact Sensors

38 Simulating Operation of a Complex Sensor Network

38 Progress in Development of Improved Ion-Channel Biosensors

40 **Electronics/Computers**

40 Using Transponders on the Moon to Increase Accuracy of GPS

40 Controller for Driving a Piezoelectric Actuator at Resonance

44 Coaxial Electric Heaters

45 High-Density, High-Bandwidth, Multilevel Holographic Memory

46 **Semiconductors & ICs**

46 Dual-Input AND Gate From Single-Channel Thin-Film FET

50 **Manufacturing & Prototyping**

50 Fabrication of Gate-Electrode Integrated Carbon-Nanotube Bundle Field Emitters

54 **Materials**

54 Photochemically Synthesized Polyimides

55 Hydroxide-Assisted Bonding of Ultra-Low-Expansion Glass

56 Optimized Carbonate and Ester-Based Li-Ion Electrolytes

58 **Mechanics/Machinery**

58 Ultrasonic/Sonic Impacting Penetrators

61 Miniature, Lightweight, One-Time-Opening Valve

(Solutions continued on page 6)

DEPARTMENTS

8 **UpFront**

10 **Who's Who at NASA**

49 **Technologies of the Month**

94 **NASA's Innovative Partnerships Program**

95 **Advertisers Index**

NEW FOR DESIGN ENGINEERS

88 **Product Focus: Materials & Coatings**

89 **New Products/Software**

SPECIAL SUPPLEMENT

71 – 87
Photonics Tech Briefs

1a – 18a
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META-1022, p. 55
Meta v. Resonant
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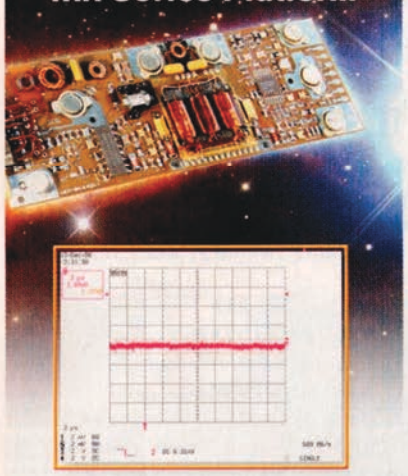

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Using Transponders on the Moon to Increase Accuracy of GPS

Ranging to the Moon would be unaffected by the terrestrial atmosphere.

NASA's Jet Propulsion Laboratory, Pasadena, California

It has been proposed to place laser or radio transponders at suitably chosen locations on the Moon to increase the accuracy achievable using the Global Positioning System (GPS) or other satellite-based positioning system. The accuracy of GPS position measurements depends on the accuracy of determination of the ephemerides of the GPS satellites. These ephemerides are determined by means of ranging to and from Earth-based stations and consistency checks among the satellites. Unfortunately, ranging to and from Earth is subject to errors caused by atmospheric effects, notably including unpredictable variations in refraction.

The proposal is based on exploitation of the fact that ranging between a GPS satellite and another object outside the atmosphere is not subject to error-inducing atmospheric effects. The Moon is such an object and is a convenient place for a ranging station. The ephemeris of the Moon is well known and, unlike a GPS satellite, the Moon is massive enough that its orbit is not measurably affected by the solar wind and solar radiation.

According to the proposal, each GPS satellite would repeatedly send a short laser or radio pulse toward the Moon and the transponder(s) would respond by sending back a pulse and delay information. The GPS satellite could then compute its distance from the known position(s) of the transponder(s) on the Moon.

Because the same hemisphere of the Moon faces the Earth continuously, any transponders placed there would remain continuously or nearly continuously accessible to GPS satellites, and so only a relatively small number of transponders would be needed to provide continuous coverage. Assuming that the transponders would depend on solar power, it would be desirable to use at least two transponders, placed at diametrically opposite points on the edges of the Moon disk as seen from Earth, so that all or most of the time, at least one of them would be in sunlight.

This work was done by Konstantin Penanen and Talso Chui of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov.
NPO-43160

Controller for Driving a Piezoelectric Actuator at Resonance

Unpredictable variations in resonance frequency are tracked.

NASA's Jet Propulsion Laboratory, Pasadena, California

A digital control system based partly on an extremum-seeking control algorithm tracks the changing resonance frequency of a piezoelectric actuator or an electrically similar electromechanical device that is driven by a sinusoidal excitation signal and is required to be maintained at or near resonance in the presence of uncertain, changing external loads and disturbances. Somewhat more specifically, on the basis of measurements of the performance of the actuator, this system repeatedly estimates the resonance frequency and alters the excitation frequency as needed to keep it at or near the resonance frequency. In the original application for which this controller was developed, the piezoelectric actuator is part of an ultrasonic/sonic

META-1022, p. 56
Meta v. Resonant
IPR2025-00823

drill/corer. Going beyond this application, the underlying principles of design and operation are generally applicable to tracking changing resonance frequencies of heavily perturbed harmonic oscillators.

Resonance-frequency-tracking analog electronic circuits are commercially available, but are not adequate for the present purpose for several reasons:

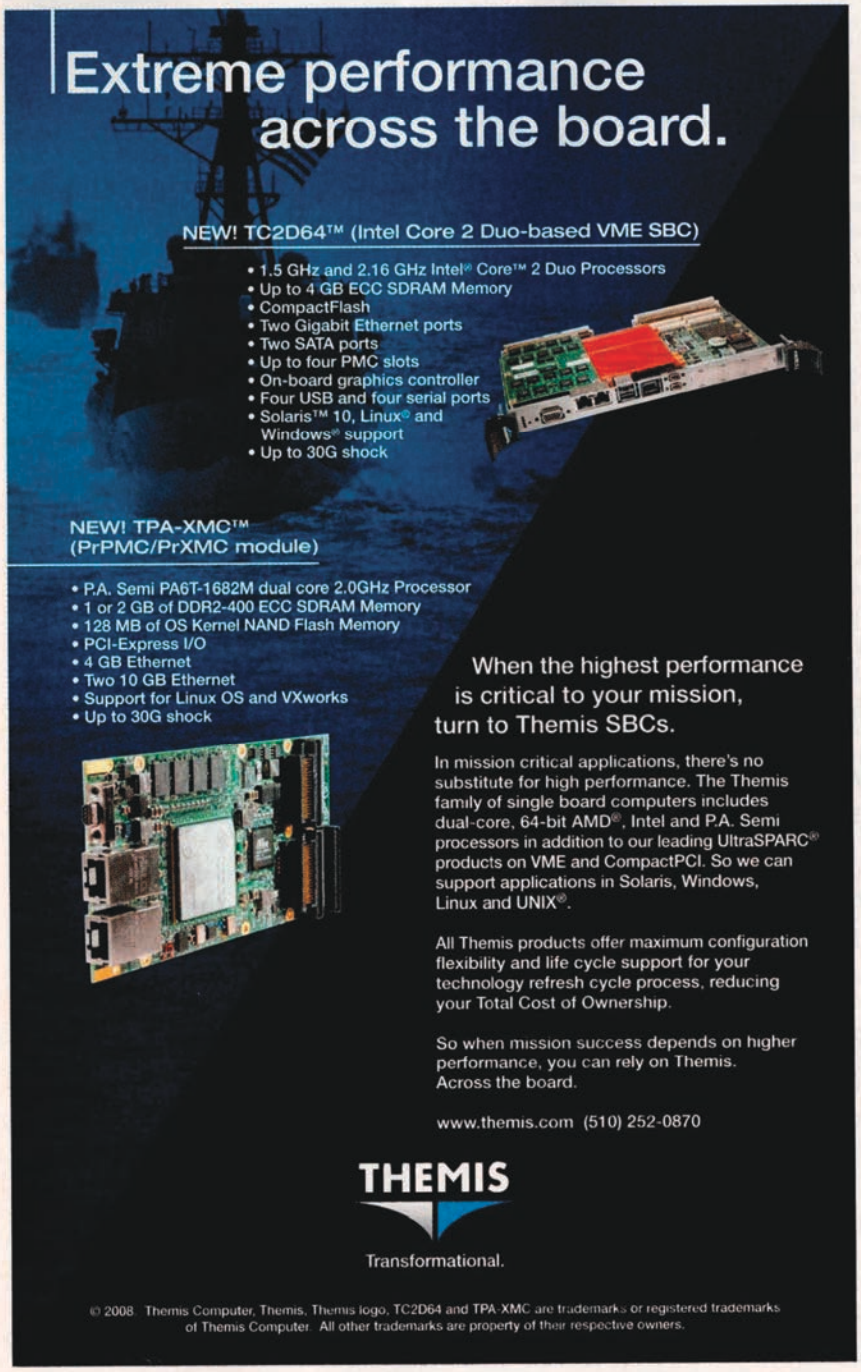
- The input/output characteristics of analog circuits tend to drift, often necessitating recalibration, especially whenever the same controller is used in driving a different resonator.
- In the case of an actuator in a system that has multiple modes characterized by different resonance frequencies, an analog controller can tune erroneously to one of the higher-frequency modes.
- The lack of programmability of analog controllers is problematic when faults occur, and is especially problematic for preventing tuning to a higher-frequency mode.

In contrast, a digital controller can be programmed to restrict itself to a specified frequency range and to maintain stability even when the affected resonator is driven at high power and subjected to uncertain disturbances and variable loads.

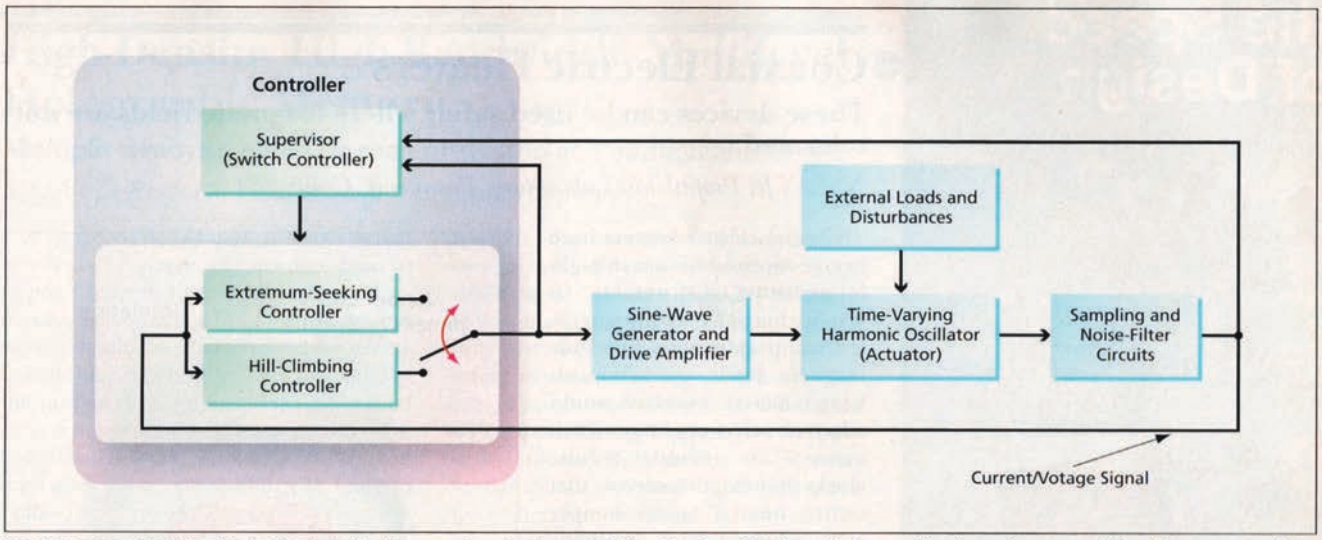
The present digital control system (see figure) is implemented by means of an algorithm that comprises three main subalgorithms: a hill-climbing control algorithm, an estimation-based extremum-seeking control (ESC) algorithm, and a supervisory algorithm. The hill-climbing algorithm is useful for coarse tracking to find and remain within the vicinity of the resonance. The ESC algorithm is not capable of coarse resonance tracking, but is capable of fine resonance tracking once the estimates of parameters generated by the hill-climbing algorithm have converged sufficiently. On the basis of the parameter-estimation errors, the supervisory algorithm switches operation to whichever of the other two algorithms performs best at a given time.

For the purpose of the control algorithm, the performance of the actuator is quantified in terms of the ratio between the time-averaged drive-voltage amplitude and the time-averaged drive current amplitude during a sampling time period. In the hill-climbing algorithm, the excitation frequency during the next sampling period is incremented or decremented by an arbitrary fixed step. If the increment or decrement results in an increase in the current/voltage ratio, then the direction of change (increase or decrease, respectively) of frequency is accepted and another such change (increment or decrement, respectively) is made during the following sampling period. If, on the other hand, the increment or decrement results in a decrease in the current/voltage ratio, then the direction of change of frequency during the following sampling period is reversed. The process as described thus far is repeated, causing the current/voltage performance to climb to one of the resonance peaks and eventually to oscillate about the peak. In order to prevent climbing of one of the undesired higher-frequency resonance peaks, it is necessary to choose the starting excitation frequency near the desired peak and to impose a limit on the excursion from the starting frequency.

Once the excitation frequency has begun to oscillate about the peak, the supervisory algorithm switches operation to the ESC algorithm, which uses past as well as present input/output data to make a least-squares estimate of the resonance frequency. The estimation task involves



META-1022, p. 57
Meta v. Resonant
IPR2025-00823



This **Resonance-Tracking Controller** includes three main subsystems that function together to effect a combination of coarse and fine frequency tracking optimized to maintain operation at a desired resonance and avoid undesired resonances.

updating two scalar parameters of a quadratic model that represents the input/output map of the actuator resonance. After each sampling period, the new input/output data pair is added to the collection of past data pairs, such that information regarding the input/output relationship of the actuator increases over time; in other words, as the input/output information comes in, the algorithm tries to improve the fit between the quadratic model near resonance and all the past input/output data up to the current time. Once the estimated parameters have converged sufficiently, the excitation frequency is updated according to a simple formula that represents a maximizer associated with the quadratic model. In the event that the estimates begin to diverge beyond a specified limit, the supervisory algorithm switches operation back to the hill-climbing algorithm.

This work was done by Jack Aldrich, Yoseph Bar-Cohen, Stewart Sherrit, Mircea Badescu, Xiaoqi Bao, and Zensheu Chang of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov. NPO-43519

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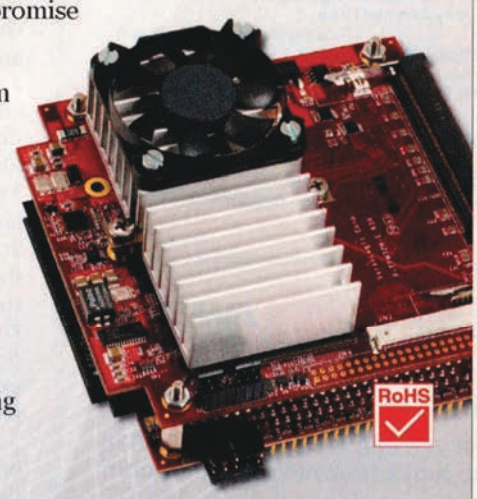

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META-1022, p. 58
Meta v. Resonant
IPR2025-00823

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